The Effects of Protection on the Diversity of Juniper Stands in Zagros Forests, Iran

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Abstract

It was aimed to investigate the efficiency of forest protection practices on the biodiversity conservation in Juniper stands of Zagros forests, Iran in this research. Two protected and unprotected Juniper stands were selected in Zagros forests as the study areas. They were inventoried by line intersect sampling method to estimate the number of tree and shrub species in four height levels (<0.5m, 0.5-1.0m, 1.0-1.5m, 1.5m<). The results showed that the biodiversity and richness of the protected Juniper stand were significantly higher that of the unprotected one. It is also necessary to mention that the indicators in each height level were higher in the protected stand but the differences were insignificant. It was concluded that although the species diversity was improved in the protected Juniper stand but more tending operations are necessary to make significantly different diverse stands by protection strategies in Juniper forests of Zagros region.

Keywords

Biodiversity; Evenness; Juniper; Managed stand; Richness; Zagros

Introduction

Biodiversity, playing a critical role in sustainable development and poverty eradication as well as maintainance of ecosystem resilience to exogenous shocks such as extreme weather events, that is important to human well-being, livelihoods and cultural integrity, is recognized as underpinning the functioning of ecosystems by maintaining flows of ecosystem services (Czajkowski *et al*. 2009; Michel and Winter 2009; Geburek *et al*. 2010). Biodiversity monitoring thus is an essential prerequisite to support management decisions to maintain multiple ecosystem functions in the long term (Failing and Gregory 2003; Kallio *et al*. 2008; Gardner *et al*. 2010; Corona *et al*. 2011). Its maintenance is also a key management objective and a requisite for sustainable development and it is necessary to understand the dynamics and heterogeneity of natural ecosystems in order to provide guidelines for management (Torras and Saura 2008; Boutin *et al*. 2009; Czajkowski *et al*. 2009).

There are several approaches to define the term biodiversity, most often, including the concepts of genetic, species, and ecosystem diversity or alternatively the concepts of compositional, structural, and functional diversity. In general, the biodiversity of a specific ecosystem is assessed by determining its species diversity (Failing and Gregory 2003; Gordon and Newton 2006; Geburek *et al*. 2010). This definition considered in the present research has been utilized to evaluate the biodiversity of an ecosystem.

The world has confronted an unprecedented reduction of biodiversity occurring in virtually every ecosystem in the world. Forest ecosystems, which can be defined by the presence of tree canopies that cover more than 10% of a site, have not excluded from the loss of biodiversity. In addition to biodiversity conservation, forest ecosystems supply a wide range of commodities in reaction to an expanding human population, including structural materials, fuels, and medicines, along with a wide range of critical ecosystem services including nutrient cycling, climate regulation, maintaining water balances and carbon sequestration (Jones and Lynch 2007; Czajkowski *et al*. 2009; Motz *et al*. 2010). It is clear that species diversity can play a critical role in affecting ecological processes. The loss of biodiversity stems largely from direct and indirect human activities, including deforestation, fragmentation and the degradation of forest habitats through road construction or the introduction of exotic species. It also is characterized with a decrease in the abundance and distribution of species, the fragmentation of habitats, as well as reductions in habitat quality (Czajkowski *et al*. 2009; Heino *et al*. 2009; Klenner *et al*. 2009; Motz *et al*. 2010). Consequently, assessment and monitoring on biodiversity status should be regarded as strictly tied to sustainable forest management (SFM). The maintenance and enhancement of biodiversity is significant within any framework of SFM in its own right. This integration of biodiversity under the umbrella of SFM is particularly important as it is increasingly clear that setting aside conservation areas will not be sufficient to preserve the diversity level required to maintain the evolutionary potential of tree populations and forest ecosystems (Lexer and Seidl 2009; Corona *et al*. 2011). Maintainance of the biodiversity of forest ecosystems failed to appear in forest policy documents explicitly before the 1990s, but implicitly, the diversity of forest stands is always a concern whenever the goals of growing protective, recreational, pest-resistant forests are expressed, as it is well-known that these functions could be enhanced by promoting forests of indigenous types, which are expected to be more rich and diverse. Therefore, analysis on diversity of woody vegetation is considered a reasonable simplification to assess the effectiveness of forest policy instruments over a medium-term (half-century) period (Anand *et al*. 2010). The effects of forest management strategies and silvicultural methods on forest biodiversity conservation have been studied by many authors (Polyakov and Teeter 2005; Ghasemi and Fataei 2006; Torras and Saura 2008; Boutin *et al*. 2009; Lexer and Seidl 2009; Eyre *et al*. 2010).

One of the most applicable strategies to conserve forest biodiversity is the establishment of protected areas (PAs). It is becoming widely accepted that PAs are the most effective way to conserve biodiversity (Anand *et al*. 2010). A few authors investigated the effects of conservation on forest biodiversity (Abasi *et al*. 2009; Heino *et al*. 2009). Fencing these areas is a major forest management practice utilized in different regions of Iran considering Zagros forests. However, the response of biodiversity to this forest management practice is not well-studied in the region, which is considered a biodiversity hotspot and has been subjected to human impacts for centuries (Abasi *et al*. 2009). Furthermore, extensive surveys on biodiversity in protected and managed areas have not been conducted for a majority of taxonomic groups and ecosystem types in Zagros forests.

It is believed that protecting the Juniper stands in Zagros forests, Iran, by fencing can improve the biodiversity of these ecologically valuable stands. Our study aims to assess the effects of this forest protection practice on forest biodiversity indicators in the Zagros region (W IRAN), considering the two fenced and unfenced Juniper stands with similar geographical circumstances. An analysis has been performed at the stand level using a large data set based on line intersect sampling method inventoried in the mentioned stands, then indicators of biodiversity of trees and shrubs between the protected fenced and unfenced stands have been compared.

Materials and Methods

Study area

The study was conducted in Fars province, i.e., in the southern part of Zagros forests, Iran (Fig. 1). This region has a semi-mediterranean climate characterized by a mean annual temperature of 19.4 °C and a mean annual precipitation of about 284 mm.

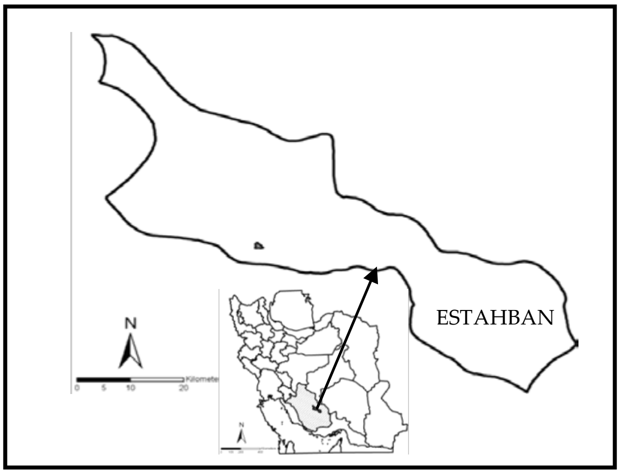


FIG. 1 MAP IDENTIFYING THE LOCATION OF FARS PROVINCE RELATIVE TO IRAN, WITH ESTAHBAN COUNTY INDICATED

Two protected and unprotected Juniper stands chosen to compare their species diversity were located in Estahban county and their surface areas were 53.8 and 58.9 ha, respectively. The protected stand was fenced since 1997. The forests studied ranging from 779300 to 781000 E and from 3223500 to 3224700 N were located on the slopes of Zagros mountains in between 1800 and 2400 m above sea level (Fig. 1). The forest stands studied were almost exclusively composed of mainly Juniper (*Juniperus polycarpos*) and Maple (*Acer cinerascens*), though other tree species such as Almond (*Amygdalus scoparia*), Wild Pistachio (*Pistacia mutica*) and Wild Cherry (*Cerasus avium*) may be locally dominant or co-dominant.

Forest sampling

Biodiversity assessment by different indicators needs the number of species in a given region. However, determining the number of species (either in total or for a species group such as trees) is much difficult and time consuming. Full enumeration of individuals and species is also expensive. So the unbiased sample-based estimation of species number has been studied for decades (Lam and Kleinn 2008; Motz *et al*. 2010). Various field methodologies have been proposed for this purpose. One of the most applicable ones in woodlands is line intersect sampling (LIS) method, a well-known method to estimate densities of species of interest in relation to biodiversity studies (Ringvall *et al*. 2000; Ridgway 2010; Yamamoto *et al*. 2011). Therefore, thirty one non-repeated transects were carried out within each of the two community forests from September to October 2011 (62 transects in total). The 50 m line intersects directed to N were surveyed in a 100 × 150 m mesh all over the study area. The species kind and their number in four height levels (<0.5, 0.5-1.0, 1.0-1.5, 1.5< m) were determined for further analysis. The height levels were selected to separate the age of each species and perform a better study on the natural regeneration of different species in the studied juniper stands, managed and unmanaged.

Forest biodiversity indicators

Assessment on the status of biodiversity requires suitable indicators that are tools to assess key factors of forest biodiversity. An indicator is defined as a quantitative or qualitative parameter which can be assessed in relation to the criterion maintaining a certain biodiversity level which should be monitored periodically (Geburek *et al*. 2010). There are a number of indicators available for characterizing biodiversity, each of which offers only a simplified way to describe a complex entity such as an ecosystem (Anand *et al*. 2010).

To characterize the diversity of woody vegetation in the study area, we selected richness, evenness and biodiversity indicators (Anand *et al*. 2010; Motz *et al*. 2010). Each one of the mentioned indicators can be assessed by different indices. The most famous ones have been applied here as explained in the following.

Richness

Species richness (or the number of species) is currently the most widely used diversity measure. Different methods have been suggested by many investigators to measure this index. The oldest and the simplest measure of the species richness (*s*) is the number of species (*n*) as the most common method among others (Hvenegaard 2011).

Evenness

Species evenness (or relative species abundance) in a community is another factor that affects diversity. One of the most frequent methods of evenness measurement is Simpson (Krebs 1989). Simpson's evenness index is defined as:

[1]
$$E_{1/D} = \frac{1/D}{n}$$

where D is Simpson's biodiversity index and n is the number of species. The second general method is Camargo suggested by Camargo (1993). As for the case for Simpson, this method is less sensitive to rare species. Camargo's evenness index is calculated as:

[2]
$$E' = 1.0 - \left(\sum_{i=1}^{n}\sum_{j=i+1}^{n}\left[\frac{|p_i - p_j|}{n}\right]\right)$$

where p is species frequency and n is the number of species. Smith and Wilson (1996) suggested a new method based on species frequency. This method is sensitive to rare and dominant species of the community and measured through the equation:

[3]
$$E_{\mathrm{var}} = 1 - 2/\pi \arctan\left[\sum_{n_1=1}^{n}\left(\ln(x_{n_1}) - \sum_{n_2=1}^{n}(\ln(x_{n_2}))/n\right)^2 \Big/ n\right]$$

where n_1 is the number of individuals of the first species, n_2 is that of the second species and n is the number of all individuals in all species.

Biodiversity

Biodiversity is a combination of richness and evenness. Simpson, the most popular and frequently used biodiversity index (Nagaoka 2001; Nagendra 2002) defines the probability that two equal individuals, selected randomly, belong to different species. This method is measured by:

[4]
$$1 - D = 1 - \sum_{i=1}^{n}(p_i)^2$$

where n is the number of species and p_i is the relative frequency of each species. The other common method of biodiversity measurement is Shannon-Wiener, which estimates the average uncertainty in predicting which species each randomly selected individual belongs to. The following equation is applied:

[5]
$$H' = \sum_{i=1}^{n}(p_i)(\log_2 p_i)$$

where n is the number of species and p_i is the relative frequency of each species. The third method of biodiversity estimation is Brillouin similar to Shannon-Wiener applied when random selection of samples is doubtful and defined as:

[6] $$\hat{H} = \frac{1}{N}\log(\frac{N!}{n_1!n_2!})$$

where n_1 is the number of individuals of the first species, n_2 is that of second species and n is the number of all individuals in all species (Krebs 1989).

Statistical methods

To describe the levels of the species diversity of the managed and unmanaged juniper stands, the mentioned biodiversity indicators were studied following Krebs (1989). The indicators have been analysed by calculating the related indices of each indicator. Differences in biodiversity indicators between the managed and unmanaged juniper stands were tested using *t*-test (Heino *et al*. 2009).

Results

The most frequent woody species found in more than half of the plots are *Juniperus polycarpos*, *Acer cinerascens*, *Pistacia atlantica* and *Cerasus avium*. Similarly, *Rhamnus* spp., *Amygdalus* spp., *Berberis* spp. and *Ephedra spp*. are the shrubby species found in the studied stands. The results showed that the biodiversity of all species was higher in the protected stand compared to the unprotected one (FIG. 2) but it was vice versa in the evenness of all species (FIG. 3). For biodiversity, three indices of Simpson, Shannon-Wiener and Brillouin were 0.83 (±0.03) and 0.77 (±0.06), 2.25 (±0.23) and 1.76 (±0.31), 1.6 (±0.18) and 1.2 (±0.23) in the fenced and unfenced stands, respectively. For evenness, the quantitative amount of three indices of Simpson, Camargo and Smith&Wilson were 0.72 (±0.05) and 0.78 (±0.06), 0.72 (±0.04) and 0.75 (±0.05), 0.81 (±0.04) and 0.84 (±0.04) in the fenced and unfenced stands, respectively. Mean richness of all species were 6.35 (±0.84) for protected stand and 4.52 (±0.88) for unprotected stand (FIG. 4).

We investigated a total of 35 and 28 woody and shrubby species in four height levels in two fenced and unfenced Juniper stands, respectively. The results showed the amount of biodiversity indicators in four height levels of the species in the studied stands. The related indices of richness and biodiversity of all height levels were clearly higher in protected than that in unprotected stands, but it is not true for the indices of evenness. The measurements showed that the evenness of 1.5< m species were obviously higher in the unfenced stand but the other height levels had higher evenness in the fenced stand (TABLE 1 & 2).

As well the box plots of the biodiversity indicators for

TABLE 1 PATTERNS OF DIVERSITY OF THE SPECIES IN THE PROTECTED STAND (n=31)

Indicators and Indices		**<0.5 m**	**0.5-1.0 m**	**1.0-1.5 m**	**1.5< m**
Richness		7	10	10	8
Evenness	Simpson	0.53	0.68	0.59	0.38
	Camargo	0.55	0.63	0.59	0.38
	Smith& Wilson	0.63	0.54	0.66	0.29
Biodiversity	Simpson	0.704	0.864	0.85	0.68
	Shannon-Wiener	2.063	2.97	2.9	1.98
	Brillouin	1.79	2.69	2.526	1.887

TABLE 2 PATTERNS OF DIVERSITY OF THE SPECIES IN THE UNPROTECTED STAND (n=31)

Indicators and Indices		**<0.5 m**	**0.5-1.0 m**	**1.0-1.5 m**	**1.5< m**
Richness		6	9	7	6
Evenness	Simpson	0.42	0.53	0.62	0.51
	Camargo	0.435	0.501	0.59	0.49
	Smith& Wilson	0.425	0.44	0.604	0.403
Biodiversity	Simpson	0.68	0.804	0.79	0.68
	Shannon-Wiener	1.95	2.56	2.397	1.909
	Brillouin	1.69	2.26	2.08	1.78

the two stands confirmed the results mentioned above. As shown in FIG. 2 & 4, the biodiversity and richness of all species of the protected stand were higher and the differences were significant in *t*-test (TABLE 3). On the other hand, the evenness of all species of the unprotected stand was higher in the three related indices (FIG. 3) but the differences were not meaningful in *t*-test (TABLE 3).

Although the diversity indicators of all species showed that richness and biodiversity of all species are significantly higher in the protected Juniper stand, the case is not the same for the investigated four height levels. The *t*-test analysis of the results showed that although the biodiversity and richness at four studied height levels are higher in the protected stand compared to the unprotected one but it is not significant (TABLE 4).

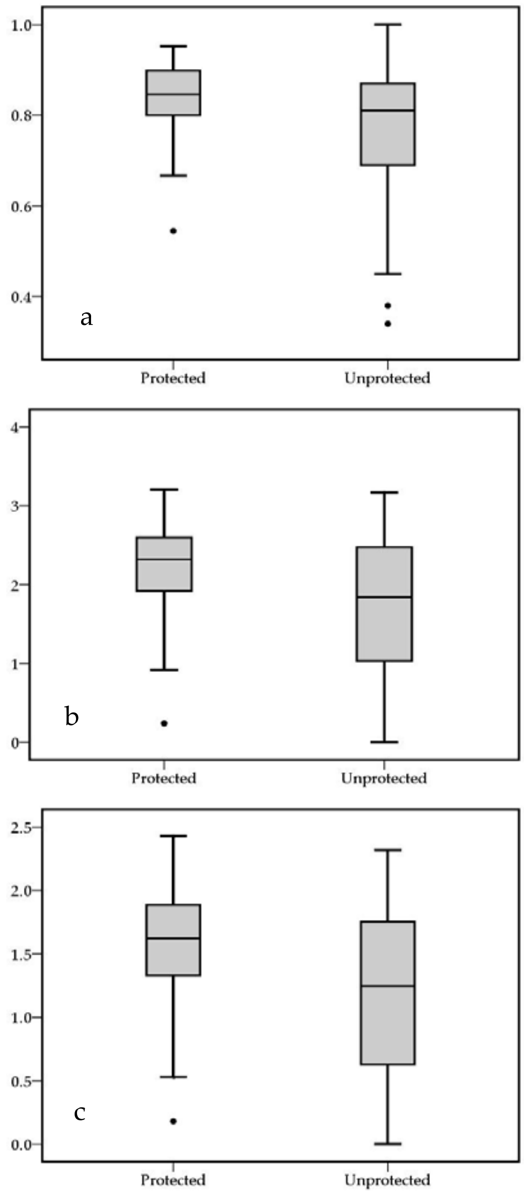
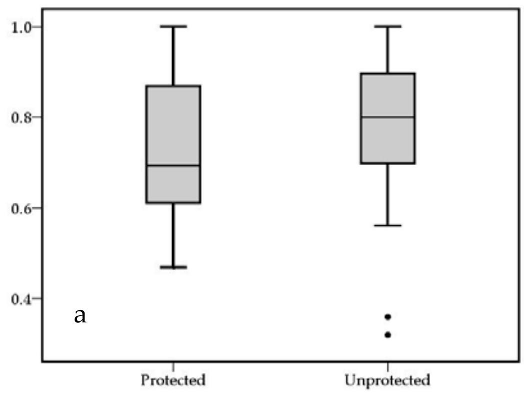


FIG. 2 BOX PLOTS SHOWING VARIATION IN THE BIODIVERSITY OF THE SPECIES IN THE STUDIED STANDS BY: (a) SIMPSON, (b) SHANNON-WIENER AND (c) BRILLOUIN INDICES



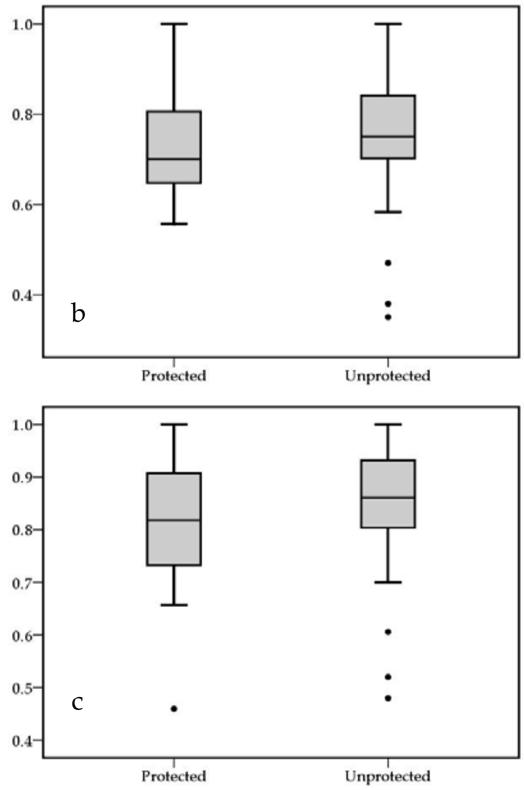


FIG. 3 BOX PLOTS SHOWING VARIATION IN THE EVENNESS OF THE SPECIES IN THE STUDIED STANDS BY: (a) SIMPSON, (b) CAMARGO AND (c) SMITH&WILSON INDICES

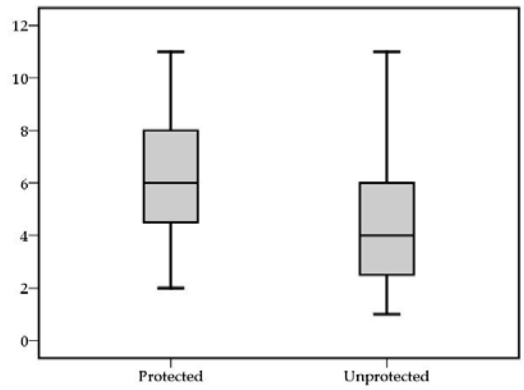


FIG. 4 BOX PLOTS SHOWING VARIATION IN THE RICHNESS OF THE SPECIES IN THE STUDIED STANDS

Discussion

Biodiversity is under threat globally and dramatically changing due to convincing evidences (Czajkowski *et al*. 2009; Klenner *et al*. 2009). Conserving forest biodiversity is a key element of regional, national and international forest management policies, agreements and guidelines. A key principle of biodiversity conservation in native forests managed for multiple commodities is the maintenance of stand structural complexity (Barbier *et al*. 2009; Eyre *et al*. 2010). Therefore, we investigated the results of fencing as a protection strategy in Zagros forests on the biodiversity of species in Juniper stands. In the following, we aim at finding reasons for the results and discuss the efficiency of this strategy for future applications.

First of all, our findings showed that the richness of all species in all height levels was significantly higher in the protected (s=35) compared to the unprotected stand (s=28) (TABLE 1, 2 & 3). As the region is located in the slopes of Zagros mountains that most of the population are depended on animal husbandry, the fencing strategy prevented the entrance of livestock to graze in the region. So the natural regeneration has the opportunity to be established and the richness, the number of species in a region, increases as it happened in the protected Juniper stand. The natural regeneration of some species like *Juniperus polycarpos*, *Pistacia mutica*, *Rhamnus* spp. and *Berberis* spp. Are found only in the protected Juniper stand. In addition, the richness of different species with varying height levels was higher in the protected stand although it was not significant. It thus can be concluded that fencing improves the richness of species in the studied stands although the results showed that the increase was insignificant for different species groups in *t*-test (TABLE 4). The same conclusion was suggested by Heino *et al*. (2009) and Abasi *et al*. (2009) who found a significant difference between the richness of protected stands compared to other stands.

TABLE 3 THE T-TEST ANALYSES OF THE DIVERSITY INDICATORS OF ALL SPECIES IN THE PROTECTED VERSUS UNPROTECTED STANDS (ns=NOT SIGNIFICANT, *=p<0.05)

Indicators and Indices		All species
Richness		3.424*
Evenness	Simpson	0.599^{ns}
	Camargo	0.228^{ns}
	Smith&Wilson	0.152^{ns}
Biodiversity	Simpson	1.973*
	Shannon-Wiener	2.61*
	Brillouin	2.883*

TABLE 4 THE T-TEST ANALYSES OF THE DIVERSITY INDICATORS OF PROTECTED VERSUS UNPROTECTED STANDS (ns=NOT SIGNIFICANT, *=p<0.05)

Indicators and Indices		<0.5 m	0.5-1.0 m	1.0-1.5 m	1.5< m
Richness		0.832^{ns}	1.04^{ns}	0.442^{ns}	0.172^{ns}
Evenness	Simpson	0.875^{ns}	0.261^{ns}	0.117^{ns}	1.226^{ns}
	Camargo	1.0^{ns}	0.172^{ns}	1.5^{ns}	1.033^{ns}
	Smith& Wilson	1.062^{ns}	0.553^{ns}	1.262^{ns}	0.161^{ns}
Biodiversity	Simpson	1.26^{ns}	0.086^{ns}	0.667^{ns}	0.825^{ns}
	Shannon-Wiener	0.168^{ns}	0.57^{ns}	1.105^{ns}	0.814^{ns}
	Brillouin	0.139^{ns}	0.256^{ns}	0.53^{ns}	1.274^{ns}

Secondly, there was a significant difference between the biodiversities of all species in the protected and unprotected stands (TABLE 3). This finding proved the results of richness of all species in the studied stands. It is also concluded that the fencing strategy is efficient not only in the improvement of richness but also in the increase of biodiversity of all species and they interestingly have the same trend in the studied stands. The box plots of richness and biodiversity of all species showed the same findings (FIG. 2 & 4). On the other hand, the biodiversity of different species in different height levels was higher in the protected stand although their differences were insignificant in *t*-test (TABLE 1, 2 & 4). Considering the results, it was concluded that the protection of Juniper stands affected the biodiversity of species in different height levels and as mentioned above, the establishment of natural regeneration during the fencing period and observation of some species that were not found in the unprotected stand resulted in the higher biodiversity in the protected stand at different height levels although the differences were not great.

Thirdly, noticeable differences can be observed in all species evenness that the box plots showed (FIG. 3) but they were not statistically significant (TABLE 3). Unlike richness and biodiversity, the evenness of unprotected Juniper stand was higher than that of the protected one. Although the evenness of protected Juniper stand was lower compared to the other one, the combination of richness and evenness makes the biodiversity of a stand significantly higher in the protected one. It is also important to note that the analysis of evenness can enrich the analyses of biodiversity in a stand (Barbier *et al*. 2009; Boutin *et al*. 2009). There was much variation in the evenness of protected and unprotected Juniper stands in different height levels and this indicator was interestingly higher in the protected stand in each group (TABLE 1 & 2), although this difference was not significant in each one of the studied height levels (TABLE 4). This result is in contrast with the total evenness of the stands (FIG. 3).

The results showed that the tree and shrub species in each one of the investigated height levels are not efficiently established in the protected stand. This finding may be attributed to the fact that there were no significant differences in the biodiversity, richness and evenness of the species in different height levels between protected and unprotected stands (TABLE 3 & 4). It is concluded that more tending operations are necessary to be performed beside fencig to achieve a significant difference between the biodiversity of each height level in the protected Juniper stand although the protection strategy applied in the studied stand has improved the biodiversity of all species.

Conclusion

There were three main achievements in this study. Firstly, significant differences have been found in the biodiversity and richness of all species between the protected and unprotected Juniper stands. This finding suggests that the protection of the Juniper stand from livestock grazing and other human impacts has significantly improved the woody species diversity. It is believed, however, that our result should not be regarded as an indication that forest conservation by fencing is the only way to improve the biodiversity of Juniper stands. It is essential to perform other tending operations (e.g. thinning, pruning, weeding, etc.) simultaneously to help imroving the biodiversity of the fenced stands. Secondly, no significant difference has been observed in the biodiversity of tree and shrub species in different height levels between the studied stands. This finding suggests that the fencing period is not enough for a better establishment of natural regeneration to result in a significantly higher biodiversity of the protected Juniper stand. Therefore, planting with suitable species might be necessary to facilitate natural regeneration of the present species. Thirdly, the findings of this study showed that the biodiversity of protected and unprotected Juniper stands are greatly affected by the richness of woody species. The results showed that although the evenness of the unprotected stand was higher but the biodiversity of this stand was free from influence by this difference.

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